J. Amer. Soc. Hort. Sci. 117(4):578-583. 1992.

Solubility and Application Rate of Controlled-release Fertilizer Affect Growth and Nutrient Uptake in Containerized Woody Landscape Plants

Peter R. Hicklenton and Kenneth G. Cairns
Agriculture Canada Research Station, Kentville, N.S. B4N 1J5, Canada

Additional index words. Juniperus horizontals 'Plumosa Compacta', *Cotoneaster dammeri* 'Coral Beauty', Andorra juniper, ornamentals, Nutricote

Abstract. **Nutrient release from Nutricote Type 100 (100-day N release; 16N-4.4P-8.1K), and from a 1:3 mixture of Nutricote Type 40 (40-day N release; 16N-4.4P-8.1K) and Type 100 was affected by time and temperature. The Type 40/100 mixture released nutrients more rapidly over a 5 to 35C range in laboratory studies. Seasonal growth of containerized cotoneaster *(Cotoneaster dammeri* C.K. Schneid 'Coral Beauty') and juniper *(Juniperus horizontalis* Moench. 'Plumosa Compacta') increased with increasing application rates of either Nutricote Type 100 or a 1:3 mixture of Type 40/100 over the range 2-10 kg·m^3. Between 25 June and 27 July, cotoneaster grew more rapidly in media with Type 40/100 Nutricote, but by the end of the season (27 Sept.), fertilizer type showed no effect on plant dry weight. Shoot N was higher in cotoneaster plants grown with Type 40/100 Nutricote than with the Type 100 formulation during the first 2 months of growth, reflecting the more rapid release and uptake of N from the mixture. During the last month the situation was reversed, as nutrients from the Type 40/100 mixture were depleted. Potassium and P shoot concentrations were not affected by fertilizer type. Juniper growth and shoot concentrations of N, K, and P were not affected by fertilizer type at any time during the season. The results provided no evidence that seasonal growth could be enhanced in either cotoneaster (grows rapidly) or juniper (slower growing) by mixing rapid and more slowly releasing types of Nutricote.**

Controlled-release fertilizers (CRF), sometimes considered a useful adjunct to a liquid fertilization program for containerized nursery crops, may also be used as the sole source of N, K, and P. Exclusive use of CRF can greatly reduce the quantities of these nutrients that are leached in runoff water (Rathier and Frink, 1989; Sharma, 1979), thus protecting groundwater from pollution. Several studies have reported satisfactory growth of various woody ornamentals in which N, K, and P requirements were met entirely by a preplant application of CRF (Blessington et al., 1981; Worral et al., 1987), but optimum formulations, levels, and application strategies differ greatly.

While there are many CRF formulations, the resin-coated materials are one of the most popular for containerized nursery crop production in North America. Nutrient release from these fertilizers is influenced by temperature, by the thickness of the resin coating (Rutten, 1980), and by the concentration of a release inhibitor in the granule (Shibata et al., 1980). During the late 1980s, Nutricote (Chisso-Ashai Fertilizer Co., Tokyo) CRF became very popular in Canadian nurseries due, in part, to the wide selection of types, each with different nutrient-release characteristics. Recognizing the need to provide nutrients rapidly in the early season when container temperatures in northern areas are low, the manufacturer has recommended preplant incorporation of mixtures of rapidly releasing and slow-releasing types so that supply of nutrients is equalized throughout the season Chisso-Ashai Fertilizer Co. (undated). We found no information concerning the release characteristics of such mixtures or whether their use is beneficial to plant growth. Moreover, recommended rates of fertilizer incorporation are highly generalized and give the nursery operator little guidance for the wide diversity of woody ornamental that are typically produced. The present study was designed to quantify the rate of nutrient release from Nutricote Type 100 (a 100-day N release formulation suited to short-season conditions) and a mixture of Nutricote Type 40 (a 40-day N release formulation) and Type 100 under laboratory conditions. A second objective was to assess the influence of these fertilizers at various application rates on growth and tissue nutrient contents of containerized 'Plumosa Compacta' and 'Coral Beauty' during a growing season.

Materials and Methods

Solubilization of Nutricote

Nutricote fertilizers are classified into various types on the basis of their nutrient release characteristics. Type 40 Nutricote releases 80% of constituent N and K over 40 days at a constant 25C, while Type 100 Nutricote releases the same percentage N and K over 100 days (Shibata et al., 1980). A slightly lower percentage of P is released under the same conditions. Above a minimum hydration level, nutrient release is not affected by moisture. In the first experiment, Nutricote Type 40 (16N-4.4P–8.1K) and Nutricote Type 100 (16N-4.4P-8.1K) were mixed in a 1:3 ratio. Twenty-five grams of the mixture was placed in each of 24 flasks. A similar set of 24 flasks were each filled with 25 g Type 100. Distilled water (50 ml) was added to each flask. Four flasks containing the mixture and four with Type 100 alone were placed in controlled-temperature water baths maintained at 5, 10, 15, 20, 25, 30, or 35C. After 2 weeks, the quantity of fertilizer that had solubilized was determined by decanting the water from each tube into individual beakers, washing the granules with an additional 50 ml of distilled water, transferring the washings to the beakers, evaporating to dryness, and weighing the solid residue (Lament et al., 1987). The same procedure was followed at 2-week intervals for the next 15 weeks. Regression analysis was performed with salts released

Received for publication 8 Apr. 1991. Accepted for publication 2 Dec. 1991. Contribution no. 2083 of Agriculture Canada Research Station, Kentville. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Abbreviations: CRF, controlled-release fertilizers; EC, electrical conductance.

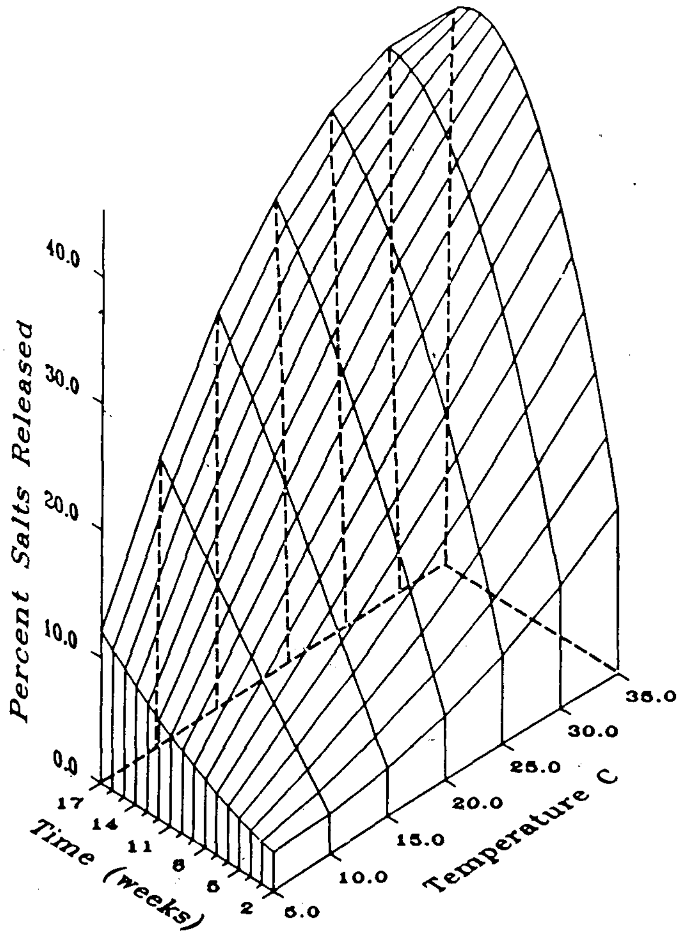

Fig. 1. Response surface relationship for the effects of temperature and time on the release of soluble salts from Nutricote Type 100 in water. Eq. $5.3 - 0.872Ti - 0.594Te + 0.027Ti^2 + 0.014Te^2 + 0.217TiTe - 0.00020Ti^2Te^2$. Ti:time (weeks); Te:temperature (C). $C_p = 7.0$; $R^2 = 0.98$.

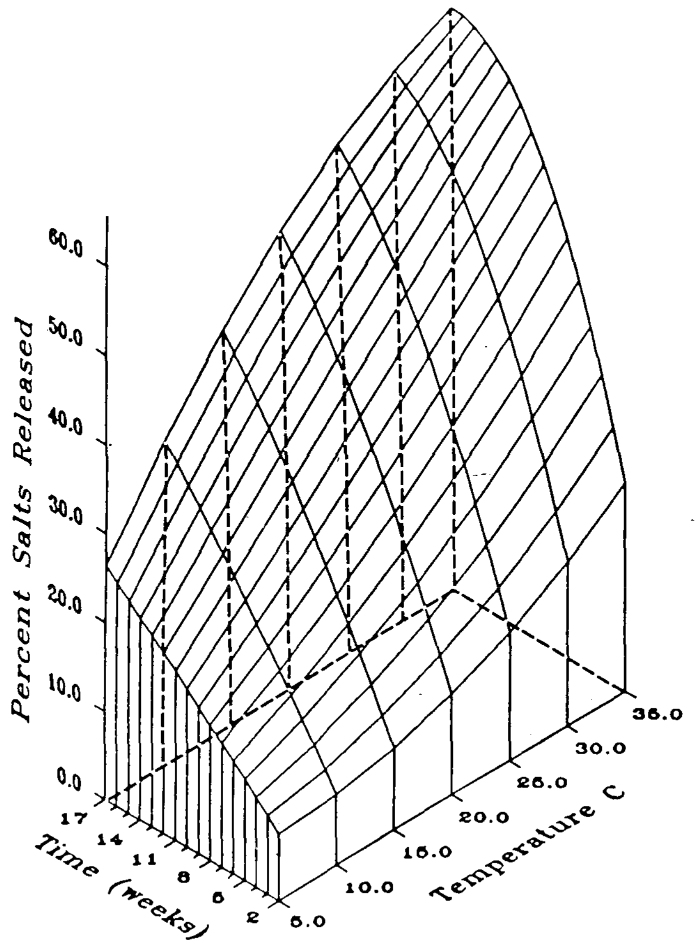

Fig. 2. Response surface relationship for the effects of temperature and time on the release of soluble salts from a 1:3 mixture of Nutricote Type 40/100 in water. Eq. $7.24 + 0.466Ti - 0.543Te + 0.019Te^2 + 0.174TiTe - 0.00016Ti^2Te^2$. Ti:time (weeks); Te:temperature (C). $C_p = 7.8$; $R^2 = 0.97$.

(expressed as a percentage of original weight) as the dependent variable and linear, quadratic, and interaction terms of time and temperature as independent variables. The final model was selected based on the significance of included independent variables, r^2, and F values of the regression model and the C_p statistic (Daniel and Wood, 1980). Only independent variables significant at $P = 0.01$ were included in the final model.

Container study

Cuttings of 'Plumosa Compacta' juniper and 'Coral Beauty' cotoneaster were taken from stock plants on 6 Nov. 1989 and 19 Mar. 1990, respectively, and rooted under intermittent mist. A growing medium was prepared by mixing 2 coarse sphagnum peat : 1 perlite : 1 sand (by volume). After being mixed, the medium was amended with 100-mesh size dolomitic lime and Nutritrace micro-element fertilizer (Chisso-Ashai Fertilizer Co.) at 2.3 and 0.5 $kg \cdot m^{-3}$, respectively, and divided into 10 batches of equal volume. Type 100 or a 1:3 blend of Type 40 and Type 100 at 2, 4, 6, 8, or 10 $kg \cdot m^{-3}$ was incorporated into each. On 24 May, rooted cuttings free of propagating medium were weighed and then planted individually into 3.5-liter green plastic containers filled with media representing the various fertilizer type and rate combinations. Containers were placed outside at a spacing of 0.5 m on a site located at Kentville Agricultural Centre (lat. °45'N). Epoxy-coated, copper-constantan thermocouples were placed at a depth of 10 cm, 3 cm from the east-facing wall of eight randomly selected containers. Medium temperatures were measured every 10 min and recorded as 2-h averages between 24 May and 27 Sept. 1990, using a datalogger (Model CR7; Campbell Scientific, Logan, Utah).

Through the 1990 growing season, each container was irrigated with 350 ml water/day via a trickle irrigation system. On the mornings of 25 June, 27 July, 27 Aug., and 27 Sept., five replicates from each fertilizer type and rate combination were placed into plastic buckets containing ≈3 liters of distilled water. The medium in each container was allowed to come to container capacity by the absorption of water from the buckets for 2 h. The buckets were then removed, excess water was allowed to drain, and 200 ml of distilled water was poured onto the medium surface in each container. The resulting leachate was collected and analyzed at 25C for soluble salt content (Yeager et al., 1983). Plants were then removed from the containers, washed free of medium, dried at 65C for 48 h, and weighed. Shoot samples were analyzed for N, K, and P as described by Hicklenton and McRae (1989).

Data were analyzed according to the randomized complete-block design and layout of the experiment. There were five blocks, each containing a single container replicate for each

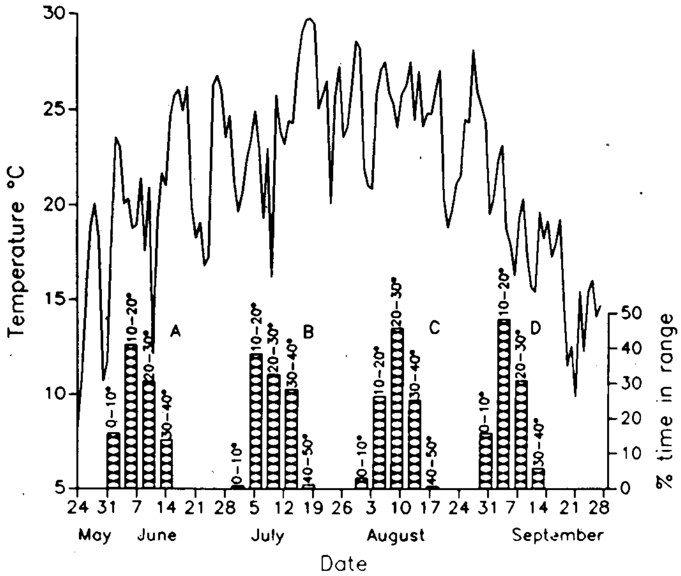

Fig. 3. Daily mean temperature (line) and percentage of time in various temperature ranges for container media for periods 25 May to 25 June **(A);** 26 June to 27 July **(B);** 28 July to 27 Aug. **(C);** and 28 Aug. to 27 Sept. **(D).** Temperatures were recorded at 10-cm depth, 3 cm from the east-facing wall of the container. Data are means for eight containers.

treatment and harvest date combination. Initial cutting fresh weight was used as a covariate (significant at $P = 0.05$) in analyses involving plant dry weight. Presented means are least-squares estimates adjusted for the covariate. Analysis revealed no significant effect of fertilizer type on juniper dry weight or shoot N, K, or P concentration, cotoneaster shoot K and P concentration, or leachate conductance. Data for these variates were therefore pooled over both fertilizer types to improve precision in the analysis of fertilizer rate effects.

Results

Solubilization of Nutricote

The quantity of soluble salts released from the Type 100 and Type 40/100 increased with temperature and time of incubation (Figs. 1 and 2). Type 40/100 solubilized more quickly than Type 100 alone; so, for example, total salts released (expressed as a percentage of original weight) were 57.4% and 42.1% for Type 40/100 and Type 100, respectively, after 17 weeks at constant 25C. At low temperature (< 10C) during the first 4 weeks of the experiment, salt release from Type 40/100 was about three times that from Type 100 alone.

Growing medium temperatures

Mean daily medium temperatures fluctuated greatly throughout the growing season (24 May to 27 Sept; Fig. 3). Mean maximum temperatures (30C) were recorded in mid-July. There were few occasions when temperatures exceeded 40C. In the early (25 May to 25 June) and late (28 Aug. to 27 Sept.) season, medium temperatures were < 10C for ≈15% of the time. The modal temperature range in each, except the third growth period (28 July to 27 Aug.), was 10 to 20C.

Plant growth and tissue nutrient content

During the 25 May to 25 June growth period neither fertilizer type nor rate had a significant effect on cotoneaster plant weight. Between 25 June and 27 August the effects of both type and rate were evident (Table 1). There were no interactions between type and rate. On 27 July and 27 Aug., plants grown in media containing Type 40/100 were heavier than those grown with Type 100 alone, and plant weight was linearly related to fertilizer rate between 2 and 10 $kg \cdot m^{-3}$. At the conclusion of the experiment, there was a similar relationship between rate and final plant weight, but the influence of fertilizer type was no longer evident.

Fertilizer type had no effect on growth of juniper. With the exception of the first harvest, plant weight increased with increasing application rate of fertilizer (Table 2). Differences between the lowest (2 $kg \cdot m^{-3}$) and higher application rates were evident by 27 July, and by the end of the season (27 Sept.) plant weights showed a marked linear response to rates over the 2 to 10 $kg \cdot m^{-3}$ range.

In all except the 25 June to 27 July growth period, fertilizer type influenced shoot N concentration in cotoneaster (Table 3). On 25 June, plants grown with Type 40/100 showed higher concentrations of shoot N than those grown with Type 100, but

Table 1. Dry weight (grams) of *Cotoneaster dammeri* 'Coral Beauty' in relation to fertilizer type and application rate, recorded on four dates during the 1990 growing season.

Nutricote rate ($kg \cdot m^{-3}$)	Date of harvest							
	25 June		27 July		27 Aug.		27 Sept.	
	T100[z]	T40/100	T100	T40/100	T100	T40/100	T100	T40/100
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	3.42	3.14	17.4	18.0	64.3	72.00	138	130
Significance[y]								
Type	NS		**				NS	
Rate	NS		**L		**L		**L	
SE[x]	0.26		1.37		5.04		7.04	

[z]T100: Nutricote 16N–4.4P–8.1K Type 100; T40/100: 1:3 mixture of Nutricote Type 40:Type 100.

[y]Significance of differences between type, rate (trend). $^{**}P = 0.01$; $^{*}P = 0.05$; NS, not significant; L, linear.

[x]SE: standard error of the mean (n = 5, df = 35).

Table 2. Dry weight (grams) of *Juniperus horizontalis* 'Plumosa Compacta' in relation to fertilizer application rate on four dates during the 1990 growing season. Data are means of plants grown with Nutricote 16N-4.4P-8.1K Type 100 and a 1:3 mix of Nutricote 40/100.

Nutricote rate ($kg\cdot m^{-3}$)	Date of harvest			
	25 June	27 July	27 Aug.	27 Sept.
2	3.05	4.12	5.56	7.58
4	3.00	5.06	6.43	9.07
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[z]Significance of trend. $**P = 0.01$; $*P = 0.05$; NS, not significant; L, linear, Q, quadratic.
[y]SE: standard error of the mean (n = 10, df = 36).

the situation was reversed in plants harvested on 27 Aug. and 27 Sept. Fertilizer type had no significant effect on shoot K or P at any harvest date. Shoot N, K, and P concentrations increased with increasing fertilizer rate at each harvest date (Table 4). The concentration of N, K, and P in shoots declined steadily between June and September, regardless of treatment.

Fertilizer type had no significant effect on shoot concentrations of N, K, or P in juniper at any harvest date. Shoot N concentration increased with fertilizer rate (Table 5) and time until 27 Aug., then declined slightly in the final growth period. While maximum N concentrations were measured in plants harvested from the 10 $kg\cdot m^{-3}$ treatments, differences over the 6 to 10 $kg\cdot m^{-3}$ range were small. Shoot K and P concentrations (Table 6) showed similar relationships to fertilizer rate and harvest date, but variations were small.

Leachate electrical conductance

Electrical conductance (EC) of cotoneaster container leachate declined more rapidly with time than juniper container leachate (Table 7). EC increased with fertilizer rate at the first three sampling dates for juniper leachate, whereas in cotoneaster leachate the effect of rate was not significant after 27 July. Fertilizer type had no significant effects on EC during the season.

Discussion

Mixing Type 40 with Type 100 increased soluble salt release as compared with Type 100 used alone, particularly at relatively low temperatures. For containerized nursery plants developing during the relatively short and cool northern growing season, this might appear to confer some advantage by improving the availability of nutrients immediately after potting. Several studies (Gilliam and Wright, 1977; Meyer and Splittstoesser, 1969; Meyer and Tukey, 1965) have shown that spring growth is influenced by tissue nutrient content established during the previous fall. For recently propagated plants with few nutrient reserves, it is likely that establishing adequate tissue nutrient contents as early as possible in the growing season is an important factor in influencing subsequent growth. Medium temperatures recorded during the 25 May to 25 June period in our container study certainly suggest that nutrient release from Type 100 would be slow. For nearly 60% of the time during the first 31 days after potting, temperatures were < 20C. At these temperatures, nutrient release from Type 40/100 would be two to three times that of Type 100 alone.

In contoneaster, extra N available from Type 40/100 was readily absorbed. Tissue N concentrations in June were higher in this treatment than in Type 100 over the entire range of fertilizer application rates. Tissue concentrations of K and P, however, were not affected by fertilizer type. Vegetative growth depends partly on the availability and uptake of N, and, in rapidly growing plants, the quantity of N absorbed depends on the demand created by the formation of new tissue (Clarkson and Warner, 1979). The increased availability and uptake of N with Type 40/100 in the early season resulted in larger plants in July and August, but by the end of September, as the total quantity of N available from the mixture declined, growth differences between fertilizer types disappeared. Increasing the fertilizer rate had a stronger and more consistent effect on growth and tissue concentrations of N, K, and P than fertilizer type, indicating that seasonal growth of cotoneaster is influenced more by the total quantities of nutrients available during the season than by availability at specific times.

Table 3. Shoot N concentration (percent dry weight) of *Cotoneaster damneri* 'Coral Beauty' in relation to fertilizer type and application rate on four dates during the 1990 growing season.

Nutricote rate ($kg\cdot m^{-3}$)	Date of harvest							
	25 June		27 July		27 Aug.		27 Sept.	
	T100[z]	T40/100	T100	T40/100	T100	T40/100	T100	T40/100
2	3.31	3.44	3.03	3.15	2.18	1.94	1.61	1.59
4	3.57	3.62	3.39	3.39	2.45	2.12	1.69	1.67
6	3.77	3.91	3.55	3.71	2.68	2.43	1.90	1.80
8	3.66	4.00	3.92	3.76	3.03	2.76	1.99	1.87
10	3.71	3.95	3.81	3.74	3.01	2.61	2.07	1.94
Significance[y]								
Type	**		NS		**		*	
Rate	**L,Q		**L,Q		**L,Q		**L	
SE[x]	0.09		0.07		0.09		0.04	

[z]T100: Nutricote 16N-4.4P-8.1K Type 100; T40/100: 1:3 mixture of Nutricote Type 40:Type 100.
[y]Significance of differences between type, rate (trend). $**P = 0.01$; $*P = 0.05$; NS, not significant; L, linear; Q, quadratic.
[x]SE: standard error of the mean (n = 5, df = 36).

Table 4. Potassium and P shoot concentrations (percent dry weight) of *Cotoneaster dammeri* 'Coral Beauty' on four dates during the 1990 growing season. Data are means of plants grown with Nutricote 16N-4.4P-8.1K Type 100 and a 1:3 mix of Nutricote Type 40/100.

Nutricote rate ($kg \cdot m^{-3}$)	K				P			
	Date of harvest							
	25 June	27 July	27 Aug.	27 Sept.	25 June	27 July	27 Aug.	27 Sept.
2	1.58	1.37	1.16	0.93	0.25	0.17	0.11	0.09
4	1.66	1.58	1.22	0.93	0.27	0.20	0.13	0.10
6	1.66	1.77	1.38	0.96	0.29	0.24	0.15	0.11
8	1.70	1.83	1.53	1.04	0.30	0.27	0.18	0.12
10	1.58	1.74	1.47	1.05	0.23	0.26	0.16	0.12
Significance[z]	*Q	**L,Q	**L,Q	**L	*Q	**L,Q	**L,Q	**L
SE[y]	0.06	0.05	0.03	0.02	0.02	0.01	0.01	0.01

[z]Significance of trend. $**P = 0.01$; $*P = 0.05$; NS, not significant; L, linear.
[y]SE: standard error of the mean (n = 10, df = 36).

Table 5. Shoot N concentration (percent dry weight) of *Juniperus horizontalis* 'Plumosa Compacta' in relation to fertilizer application rate on four dates during the 1990 growing season. Data are means of plants grown with Nutricote 16N-4.4P-8.1K Type 100 and a 1:3 mix of Nutricote Type 40/100.

Nutricote rate ($kg \cdot m^{-3}$)	Date of harvest			
	25 June	27 July	27 Aug.	27 Sept.
2	1.17	1.35	1.22	1.26
4	1.34	1.43	1.51	1.49
6	1.27	1.55	1.66	1.60
8	1.38	1.58	1.71	1.63
10	1.41	1.61	1.77	1.68
Significance[z]	*L	*L	*L,Q	**L,Q
SE[y]	0.04	0.05	0.04	0.05

[z]Significance of trend. $**P = 0.01$; $*P = 0.05$; L, linear; Q, quadratic.
[y]SE: standard error of the mean (n = 10, df = 36).

Despite differences in tissue-nutrient levels and growth of cotoneaster due to fertilizer type and rate, leachate EC values were consistent between Type 100 and Type 40/100 throughout the season and between different fertilizer application rates at the last two sampling dates. This result suggests that cotoneaster rapidly absorbed available nutrients, leaving little excess in container leachate.

In most respects, the responses of juniper to type and application rate of Nutricote differed from those of cotoneaster. Juniper plants grew more slowly than cotoneaster and were not affected by type of fertilizer at any time during the season. EC of juniper container leachate was generally higher than cotoneaster container leachate, suggesting that available nutrients were not absorbed as readily by juniper. This result is confirmed by the relative quantities of N, K, and P in shoots of the two species at various times during the season. For example, tissue concentrations of N in juniper on 25 June averaged 1.3% for an estimated total shoot content of 36 mg as compared with 3.7% or 88 mg in cotoneaster. On 27 Sept. the equivalent shoot contents were 137 mg in juniper and 1700 mg in cotoneaster. June shoot N concentrations in juniper were an average of 1.2 percentage points below that considered adequate for vigorous growth in 'Plumosa Compacta' juniper (Rathier and Frink, 1989), suggesting that juniper growth was limited by shoot levels of N in the early season. Whereas inclusion of Type 40 in the medium resulted in enhancements in shoot N concentrations and increased growth through July and August in cotoneaster, the extra N released from Type 40/100 did not benefit juniper, possibly due to uptake limitations imposed by low medium or air temperatures (Wright and Blazich, 1983).

These results do not support the contention that full-season growth can be improved by dividing a premixed application of Nutricote between rapid and more slowly releasing types. Fast-growing species, such as cotoneaster, benefit immediately from

Table 6. Potassium and P shoot concentrations (percent dry weight) of *Juniperus horizontalis* 'Plumosa Compacta' on four dates during the 1990 growing season. Data are means of plants grown with Nutricote 16N-4.4P-8.1K Type 100 and a 1:3 mixture of Nutricote Type 40/100.

Nutricote rate ($kg \cdot m^{-3}$)	K				P			
	Date of harvest							
	25 June	27 July	27 Aug.	27 Sept.	25 June	27 July	27 Aug.	27 Sept.
2	0.94	0.98	1.04	1.13	0.11	0.12	0.11	0.11
4	0.93	1.04	1.16	1.23	0.11	0.13	0.14	0.12
6	0.94	1.13	1.35	1.34	0.11	0.14	0.16	0.13
8	0.99	1.12	1.34	1.32	0.12	0.14	0.17	0.15
10	1.01	1.12	1.39	1.34	0.14	0.15	0.17	0.14
Significance[z]	*L	**L	**L,Q	**L,Q	*L	*L	**L,Q	**L,Q
SE[y]	0.04	0.02	0.02	0.02	0.01	0.01	0.01	0.01

[z]Significance of trend. $**P = 0.01$; $*P = 0.05$; L, linear; Q, quadratic.
[y]SE: standard error of the mean (n = 10, df = 36).

Table 7. Electrical conductance (μmhos·cm^{-1}) of leachate from container media sampled on four dates during the 1990 growing season. Data are means of containers with Nutricote 16N-4.4P-8.1K Type 100 and a 1:3 mix of Nutricote Type 40/100.

Nutricote rate (kg·m^{-3})	Date of measurement							
	Cotoneaster				Juniper			
	25 June	27 July	27 Aug.	27 Sept.	25 June	27 July	27 Aug.	27 Sept.
2	176	197	168	172	211	258	204	172
4	209	188	167	124	233	294	248	160
6	288	206	140	172	284	368	243	173
8	363	376	174	135	356	397	304	177
10	442	333	187	175	454	459	402	216
Significance[z]	**L	**L	NS	NS	**L	**L	**L	NS
SE[y]	24	26	14	44	24	20	31	19

[z]Significance of trend. **P = 0.01; NS, not significant; L, linear.
[y]SE: standard error of the mean (n = 10, df = 36).

the rapid release of nutrients (particularly N) in the early season, but since the extra nutrients available from Type 40/100 are quickly depleted, overall seasonal growth is not improved. Slower-growing species, exemplified by juniper, show less potential to absorb available nutrients in the early season and, therefore, exhibit no growth enhancements due to the Type 40/100 mixture. Seasonal growth in both species increases directly in response to fertilizer rate. In cotoneaster, Nutricote premixed at 4 kg·m^{-3} is sufficient to produce a salable plant from a rooted cutting in one season. Higher application rates of fertilizer are unlikely to be economical (Miller et al., 1980). In juniper, the largest and most desirable plants were obtained with Nutricote premixed at 10 kg·m^{-3}. While higher application rates may produce larger plants, costs are likely to be prohibitive.

Literature Cited

Blessington, T.M., E.J. Garvey, and L.M. Howell. 1981. Effects of application methods of controlled-release fertilizers on growth and quality of *Rhododendron obtusum* 'Hinodegiri' grown in various media. HortScience 16:676-677.

Chisso-Ashai Fertilizer Co. (undated). Nutricote controlled release fertilizer. Tech. Bul. Chisso-Aihai Fertilizer Co., Tokyo.

Clarkson, D.T. and A.J. Warner. 1979. Relationships between air temperature and the transport of ammonium and nitrate ions Italian and perennial ryegrass *(Lolium multiflorum* and *Lolium perenne).* Plant Physiol. 64:557-561.

Daniel, C. and F.S. Wood. 1980. Fitting equations to data. 2nd ed. Wiley, New York.

Gilliam, G.H. and R.D. Wright. 1977. The effects of four nitrogen levels on growth of three *Ilex* cultivars. Southern Nurseryman's Assn. Nursery Res. J. 4:28-33.

Hicklenton, P.R. and K.B. McRae. 1989. Mineral status and growth of containerized compact Andorra juniper under different irrigation and fertilizer regimens. Can. J. Plant Sci. 69:1295-1300.

Lament, G.P., R.J. Worral, and M.A. O'Connell. 1987. The effects of temperature and time on the solubility of resin-coated controlled-release fertilizers under laboratory and field conditions. Scientia Hort. 32:265-273.

Meyer, M.M. and W.E. Splittstoesser. 1969. The utilization of carbohydrate and nitrogen reserves in the spring growth of lilac. Physiol. Plant. 22:870-879.

Meyer, M.M. and H.B. Tukey. 1965. Nitrogen, phosphorus and potassium plant reserves and the spring growth of Taxus and Forsythia. Proc. Amer. Soc. Hort. Sci. 87:537-544.

Miller, M.N., D.L. Gunter, B.E. Melton, C.R. Johnson, and J.T. Midcap. 1980. Selecting economically optimal levels of fertilization and irrigation for container production of woody ornamentals. J. Amer. Soc. Hort. Sci. 105:766-768.

Rathier, T.M. and C.R. Frink. 1989. Nitrate runoff water from container grown juniper and Alberta spruce under different irrigation and N fertilization regimes. J. Environ. Hort. 7:32-35.

Rutten, T. 1980. Osmocote controlled-release fertilizer. Acta Hort. 99:187-188.

Sharma, G.C. 1979. Controlled-release fertilizers and horticultural applications. Scientia Hort. 11:107-129.

Shibata, A., S. Fufita, and S. Maeda. 1980. Nutricote-coated fertilizers processed with polyolefin resins. Acta Hort. 99:179-186.

Worral, R.J., G.P. Lament, M.A. O'Connell, and P.J. Nichols. 1987. The growth response of container-grown woody ornamentals to controlled-release fertilizers. Scientia Hort. 32:279-290.

Wright, R.D. and F.A. Blazich. 1983. Nitrogen content of Helleri Holly as influenced by ambient temperature and nitrogen fertilization rate. J. Environ. Hort. 1:46-48.

Yeager, T.H., R.D. Wright, and S.J. Donohue. 1983. Comparison of pour through and saturated pine bark extract N, P, K, and pH levels. J. Amer. Soc. Hort. Sci. 108:112-114.